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(54) Title of Invention: **UNDRAWN POLYESTER YARN AND PROCESS FOR
MANUFACTURE THEREOF**

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1. Title of Invention

Undrawn polyester yarn and process for manufacture thereof.

2. Claims

1. An undrawn polyester yarn, said yarn comprising 0.5-10% by weight of a styrenic polymer having a degree of polymerization of 20 or higher, and having a percentage increase (I) in % elongation defined by the following equation to be 8% or higher:

$$I(\%) = \left(\frac{EL_b}{EL_0} - 1 \right) \times 100$$

Wherein EL_b is the residual elongation(%) of an undrawn yarn of this invention; EL_0 is the residual elongation (%) of the undrawn yarn of this invention except for not containing any styrenic polymer component.

2. An undrawn polyester yarn as set forth in Claim 1, wherein the percent increase in elongation(%) (I) is 15% or higher.

3. An undrawn polyester yarn as set forth in Claim 1 or Claim 2, wherein the content of the styrenic polymer is 1 to 6% by weight.

4. A process for the manufacture of an undrawn polyester yarn which comprises melting a polyester containing 0.5 to 10% by weight of a styrenic polymer having a degree of polymerization of 20 or higher, spinning from a spinneret, and taking it up at a speed of 850-6,000m/min.

5. A process for the manufacture of an undrawn polyester yarn as set forth in Claim 1, wherein the content of the styrenic polymer is 1 to 6% by weight.

6. A process for the manufacture of an undrawn polyester yarn as set forth in Claim 1 or Claim 4, wherein the yarn take up speed is 2,500 to 8,000m/min.

3. Detailed Description of the Invention

The present invention relates to a novel undrawn polyester yarn and process for manufacture thereof, specifically, to an undrawn polyester yarn with excellent productivity brought by addition of a styrenic polymer and a process for manufacture thereof.

Increasing the rate of extrusion from the spinneret in the melt spinning of polyester fibers is an extremely effective way to enhance the production rate, which is highly desirable now that there is a substantial trend towards finer fineness fibers for increased productivity and for reduced yarn manufacturing costs. One of the means to achieve this objective is to use a method of increasing the yarn take up speed, thereby increasing the extrusion rate from the spinneret. However, this approach by virtue of the high take up speed tends to increase the molecular orientation of the spun yarn, thereby reducing the residual elongation (%) of the resultant undrawn yarn. As a result, as expected, this reduces the draw ratio in the subsequent drawing or draw-false twisting so that the effect of increasing the extrusion rate by increasing take up rate is cancelled out by the decrease in the draw ratio. That is, when it is desired to obtain a given fineness drawn yarn or drawn-false twisted yarn, the decrease in the draw ratio will call for reducing the polymer extrusion rate from the spinneret so as to compensate for that decrease, thereby canceling out the increased extrusion rate achieved by the increase in the take up speed. Solving

these problems will call for not increasing the molecular orientation of the spun yarn, even when the spun yarn take up rate is increased; one conceivable means, e is to provide a heated spinning cylinder immediately below the spinneret, thereby gradually cooling and solidifying the extruded polymer flow. However, such an approach is deficient in that it requires a special heater and involves an extremely difficult control of the cooling process of the spun yarn.

Separately, a process has been proposed (Japanese Patent Application Publication Kokai S53-292), which comprises copolymerizing the polyester with a chain branching agent such as pentaerythritol so as to permit increasing the extrusion rate and draw ratio, thereby improving productivity, but this approach is deficient in that process requires special polymerization conditions, the process tends to be accompanied by poor spinning conditions, and the resultant yarn will have reduced dynamic physical properties.

In order to overcome these conventional art problems, the present inventors intensively studied and discovered that addition of a specific styrenic polymer to the polyester prevents the molecular orientation of the fiber from increasing, even at a high spinning take up speed, thereby producing an undrawn polyester yarn with a high residual elongation(%), permitting drawing at a high draw ratio for higher productivity, which has led to the present invention.

The present invention is an undrawn polyester yarn, said yarn comprising 0.5-10% by weight of a styrenic polymer having a degree of polymerization of 20 or higher, and having a percentage increase (I) in % elongation defined by the following equation to be 8% or higher:

$$I(\%) = \left(\frac{EL_b}{EL_0} - 1 \right) \times 100$$

Wherein EL_b is the residual elongation(%) of an undrawn yarn of this invention; EL_0 is the residual elongation (%) of the undrawn yarn of this invention except for not containing any styrenic polymer component; and it is a process for the manufacture of an undrawn polyester yarn which comprises melting a polyester containing 0.5 to 10% by weight of a styrenic polymer having a degree of polymerization of 20 or higher, spinning from a spinneret, and taking it up at a speed of 850-6,000m/min.

The polyester used in this invention is a fiber forming polyester which is based on an aromatic dicarboxylic acid as a main acid component, such as polyethylene terephthalate, polytetramethylene terephthalate, polycyclohexane dimethylene terephthalate, polyethylene-2,6-naphthalene dicarboxylate and the like.

These polyesters may be copolymers obtained by copolymerizing other alcohols or other carboxylic acids such as isophthalic acid, 5-sodium sulfoisophthalic acid, and the like, or blends of a variety of polyesters. In particular, polyethylene terephthalate is optimum.

These polyesters optionally may contain a delusterant, heat stabilizer, UV stabilizer, anti-static agent, end-group blocking agents, fluorescent bleach agents, and the like. In terms of spinnability and yarn physical properties, these polyesters preferably have an inherent viscosity of 0.5-1.1. The styrenic polymer to be added and blended with the polyester polymer is a polymer of a styrene derivative such as styrene, α -methyl styrene, p-methoxy styrene, vinyl toluene, chlorostyrene, dichlorostyrene, and the like, or a copolymer mainly comprising these components, having a degree of polymerization of 20 or higher. A prepolymer or polymer having a degree of polymerization 20 or greater is observed to exhibit the effect of increasing the elongation (%) of the undrawn yarn, but one with a degree of polymerization less than 20 fails to show the effect of changing the molecular motion of the polyester because of its low molecular weight, thereby failing to increase the residual elongation(%). The amount of the styrenic polymer added should preferably be 0.5-10% by weight, preferably 1-6% by weight. A level less than 0.5% will give too small an effect of increasing the residual elongation(%) for this invention, while a level exceeding 10% will cause breakage of the monofilament yarn in the spinning process, and will cause many occurrences of the fiber banding around the take up roller thereby worsening the spinning conditions, in addition, resulting in decreased dynamic properties for the resultant yarn such as in tensile properties.

The addition of the styrenic polymer to the polyester can be carried out by any desired means, for example, this may be carried out in the polymerization step for the polyester or else the polyester and

styrenic polymer may be melt blended, extruded, cooled, and cut into chips. Or, both may be mixed as chips followed by melt spinning. In this case, to increase the degree of blending, it is preferred to use a screw type melt extruder. Regardless of what type of method is used, it is necessary to carry out a thorough blending with care so that the styrenic polymer is dispersed and mixed on a molecular level in the polyester. If the mixing is insufficient and the styrene polymer is mixed in as islands in the sea in the polyester, there will be no recognizable effect of increasing residual elongation(%), besides exhibiting the unfavorable phenomenon of fibrillation.

It is important for the production of the undrawn polyester yarn of this invention to have a spinning take up rate of 850-8,000m/min., in particular, 2,500-8,000m/min. If the spun yarn take up speed is too slow, there will be essentially no orientation of the molecular chains in the yarn during spinning so that the added styrenic polymer will not be able to work as a "ball bearing" with respect to the orientation of the polyester molecular chain orientation, resulting in no observable effect of increased residual elongation(%) for the undrawn spun yarn. The higher the spun yarn take up speed, the greater the effect for increasing the residual elongation(%), but if the speed exceeds 8,000m/min., the added styrenic polymer begins to work defectively, resulting in the phenomenon of so-called yarn weakening, where the tensile elongation of the spun undrawn yarn drops.

The undrawn polyester yarn thus spun and taken up will have a higher residual elongation than undrawn polyester yarn spun under identical conditions, but without addition of any styrenic polymer. That is, the percent increase in elongation (I) defined by the following formula will be not less than 8%, preferably not less than 15%.

$$I(\%) = \left(\frac{EL_b}{EL_0} - 1 \right) \times 100$$

Wherein EL_b is the residual elongation(%) of an undrawn yarn of this invention; EL_0 is the residual elongation (%) of the undrawn yarn of this invention except for not containing any styrenic polymer component.

Therefore, the undrawn yarn of this invention can be drawn at a draw ratio higher than an undrawn yarn containing no styrenic polymer.

As the residual elongation increases, the percentage improvement (J) in draw ratio as defined by the following equation also increases:

$$J(\%) = \left(\frac{DR_b}{DR_0} - 1 \right) \times 100$$

Where DR_b is the draw ratio of the undrawn yarn of this invention; DR_0 is the draw ratio of an undrawn yarn containing no styrenic polymer which would give the same residual elongation (%) level as that of the drawn yarn as resulted from drawing the undrawn yarn of this invention at a draw ratio DR_b .

In melt spinning polyester, the extrusion rate Q (g/min.) of the molten polymer is in general, expressed by the following equation:

$$Q = \frac{1}{9000} d_e \times V \times D_R$$

Where the fineness of the goal drawn yarn is d_e ; V (m/min) is the spun yarn take up speed; and D_R is the draw ratio. Therefore, increasing the draw ratio by $J\%$ at a constant spun yarn take up rate means an increase in of the extrusion rate by $J\%$ during the spinning, i.e., that the productivity can be improved by that amount. As the percentage increase in elongation (I) reaches 8% or greater, the percentage increase (J) in draw ratio becomes 5% or greater, with the resultant increase in productivity of 5% or better.

It is not clearly understood as to why the addition of the styrenic polymer in this invention brings about a specific effect of improvement in extrusion productivity. It can be perhaps speculated that as a result of overlapping the properties of the styrene polymer molecule itself such as the characteristic chemical structure of being amorphous, low mobility, and the like, with the compatibility with the polyester molecules, and conditions caused by a combination of polymers themselves such as the dispersion state in the blend, results in the function where the styrenic polymer molecule act as "[little] ball bearings" with respect to the deformation of the polyester. Perhaps due to such a mechanism, the addition of a styrenic oligomer of a degree of polymerization of less than 20 will give essentially no effect. A degree of polymerization 20 or greater will have a greater effect as the degree of polymerization is higher. However, too high a degree of

polymerization for the styrene polymer tends to reduce the spinnability somewhat, which needs attention.

Thus, the present invention can substantially improve spinning productivity by an extremely simple means and it has a very high industrial significance.

The present invention is now explained by the following examples.

Example 1

Polyethylene terephthalate chips having an inherent viscosity of 0.64 and containing 0.5% of titanium dioxide as a delusterant were dried for 4 hours at 160°C and blended with a polystyrene (product by Asahi Dow Company, Ltd., trade name Styron 683, degree of polymerization about 700) as chips at different ratios, and were melt blended in a screw type melt extruder of 25mm in diameter at 300°C for melt blending, thereby causing the polystyrene molecules to diffuse between polyethylene terephthalate molecules. Then, the molten polymer was extruded from a spinneret with 24 nozzles of 0.35mm in diameter, followed by cooling and solidifying by having air at room temperature blown at a rate of 10m/min. in a transverse blow type spinning cylinder mounted 10 to 110cm below the spinneret, treating with an oiling agent, and taking up at a speed of 3,500m/min. to obtain a 72de undrawn yarn. The spinnability, the tenacity of the resultant undrawn yarn, its residual elongation, and percentage increase in elongation(%) are as shown in the following table:

Sample No.	Polystyrene Blended (%)	Spinnability	Tenacity (g/de)	Residual Elongation (%)	Percentage Increase Elongation (I), (%)	Notes
1	0	Good	2.43	95	0	Comp.Ex.
2	0.4	Good	2.28	97	2	Comp.Ex.
3	0.6	Good	2.20	106	9	Example of this invention
4	1.2	Good	2.15	128	35	
5	5.5	Good	1.88	188	99	
6	6.5	Some monofilament breakage and the roll banding up	1.74	202	113	
7	9.5	"	1.60	217	128	"

8	11	Many occurrences of yarn breakage and spinning was impossible	-	-	-	Comp. Ex.
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Sample No. 1 received no polystyrene and Sample No. 2 had a smaller amount of polystyrene added so that both had low residual elongation(%). Sample No. 8, where the amount of polystyrene blended was too much, resulted in many occurrences of yarn breakage, thereby reducing spinnability. The residual elongation (%) of the undrawn yarn increases with an increase in the percent blending of the polystyrene, with the percentage increase in elongation (I) amounting to as high as 9 to 128%.

Example 2

Each of the undrawn yarn samples No. 1 - No. 7 in Example 1 was drawn at a preheat temperature of 75°C, a slit heater temperature of 180°C, and draw speed of 300m/min. to determine a specific draw ratio (DR) in which the residual elongation of the drawn yarn reached 25%. The results are as shown in the following table:

Undrawn Yarn	25% DR	Percentage Improvement in Draw Ratio (J) (%)
Example 1-No.1	1.65	0
Example 1-No.2	1.67	1.2
Example 1-No.3	1.74	5.5
Example 1-No.4	1.82	10.3
Example 1-No.5	2.20	33.3
Example 1-No.6	2.28	38.2
Example 1-No.7	2.35	42.4

In Examples 1 No.2 - No.7, undrawn yarns of this invention, the percentage improvement in draw ratio, that is, percent improvement in productivity amounts to 5% to 42%.

Example 3

The polyethylene terephthalate used in Example 1 was blended with 3% of polyvinyltoluene with a degree of polymerization of 550, melt extruded under the same conditions as those of Example 1, followed by taking up at different take up speeds to obtain 192de undrawn yarns. The spinnability and the residual elongation of the undrawn yarn and percentage increase in elongation (I) are as given in the following table:

Sample No.	Spun Yarn Take Up Speed (m/min.)	Spinnability	Tenacity	Residual Elongation	Percentage Increase in Elongation (I) (%)	Note
1	800	Good	1.02	528	6	Comp.Ex.
2	850	"	1.15	533	10	Examples
3	2,200	"	1.21	240	14	"
4	2,500	"	1.28	228	25	"
5	7,500	Some monofilament breakage	2.93	68	120	"
6	8,200	many occurrences of yarn breakage, poor	-	-	-	Comp.Ex

Example 4

The undrawn yarn samples No. 1 - No. 6 in Example 3 were drawn under the same conditions as those of Example 2 to obtain the specific draw ratio (DR) at which the drawn yarn had a residual elongation of 25%. The results are shown in the following table:

Undrawn Yarn	25% DR	Percentage Improvement in Draw Ratio (J) (%)
Example 3-No. 1	3.82	1.1
Example 3-No. 2	3.69	5.5
Example 3-No. 3	2.36	7.1
Example 3-No. 4	2.06	8.5
Example 3-No. 5	1.46	39.2
Example 3-No. 6	-	-

The undrawn yarns of Example 3-No.2-5 by this invention show the percentage improvement in draw ratio, that is, the percentage productivity improvement reaching 5-39%.

Example 5

A polyethylene terephthalate/5-sodium sulfoisophthalic copolymer (5 mole % of 5-sodium sulfoisophthalic copolymerized) having an inherent viscosity of 0.60 and 0.5% of delusterant titanium oxide was mixed with 3% of poly p-methoxy styrene having different degrees of polymerization and spun and taken up under same conditions as those of Example 1, except for changing the melt blend temperature to 290°C to obtain 72de undrawn yarns. For the purpose of comparison, spinning was carried without adding poly p-methoxy styrene. Spinnability and the residual elongation and percentage decrease in elongation (I) of the undrawn yarn are as given in the following table:

Sample No.	Poly p-methoxy styrene, degree of polymerization	Spinnability	Residual Elongation (%)	Percentage Increase in Elongation (I) (%)	Note
1	18	Good	55	1	Comp.Ex. Examples of this invention "
2	22	"	94	8	
3	450	"	123	41	
4	780	Some monofilament breakage and roller banding	126	5	
5	No addition	good	87	0	Comp.Ex.

Sample No. 1, which had a poly p-methoxy styrene having a degree of polymerization less than 20 showed essentially no effect for improving residual elongation. Sample No. 4 had a polystyrene derivative having a degree of polymerization somewhat too high, thereby somewhat worsening the spinning conditions, but provided an extremely large effect of improving residual elongation(%).

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